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Civilian Radioactive Waste Management System
Management and Operating Contractor

Total System Life Cycle Cost for Site Recommendation Letter Report

TDR-CRW-AD-000001 REV 00

February 2002

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DISCLAIMER

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Letter Report

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1. INTRODUCTION

This letter report is being issued to supplement the May 2001 Total System Life Cycle Cost (TSLCC) Analysis and Fee Adequacy Reports. The estimates presented there are based on several other key documents, including the *Monitored Geologic Repository Project Description Document* (Curry 2001).

No new technical information has been developed or program decisions been made that change the data provided in the May 2001 reports, and the $57.5 billion cost estimate remains valid for the current repository design, as it is documented in the MGR Project Description Document. The estimate reflects the design as conceived to accommodate high temperature operations (i.e., above boiling temperature of water); however, the design is flexible and the repository can be operated over a range of thermal operating modes.

Subsequent to completion of the May 2001 TSLCC, the program received a budget allocation for FY 2002 that was reduced from an expected $445 million to $375 million. Figure A-1 reflects that change and is a modification of Figure C-1 from the May 2001 TSLCC. The annual cost profile has been updated to reflect the fiscal year 2002 appropriation and the adjusted fiscal year 2003 costs (Appendix A).

BSC is in the process of completing the Detailed Work Plan (DWP) baseline effort for all work to be executed starting in FY02 through License Application (LA). The final date for LA, while not resolved, is expected to change from the current estimate included in the May 2001 Report resulting in an increase in the Development and Evaluation (D&E) cost up to the LA. The current TSLCC report is based on the LA date of March 2003 and indicates Development and Evaluation (D&E) (1983 – 2003) cost of $6.5 billion. Appropriations for FY 2002 are less than planned in the TSLCC contributing to the increase in this specific cost component. The near-term impact of this difference is being evaluated, but will not have any significant effect on either the TSLCC or fee adequacy reports.

The changes discussed in this letter report are not expected to impact the determination that the current 1.0 mill ($0.001) per kilowatt-hour (kWh) fee charged for electricity generated and sold using a commercial nuclear reactor is still adequate.

Burns and Roe Enterprises, Inc., was retained to perform an independent cost estimate (ICE) review of the cost estimate and associated construction schedule. Their January 2001 report (Burns and Roe 2001) commented on areas relative to schedule, cost, cost drivers, estimating methodology, and management approach. BSC was requested to review the ICE report and disposition their comments. As a result of this review, BSC found the engineering and construction schedule and the overall rate of contingency were the most significant issues raised by the ICE team.

The May 2001 TSLCC contained a section on flexible design and operating modes. In November 2001, *The Life Cycle Cost Analysis for Repository Flexible Design Concepts* report (BSC 2001a) was completed. It expands and quantifies the concepts introduced in the May 2001 TSLCC report (DOE 2001a). The current TSLCC estimate is based on a high temperature (above boiling) mode of operations that allows for the free drainage of water between widely spaced drifts. The flexible design concept allows for variations in the temperatures at the drift wall and waste package surfaces. The flexible design concepts analyzed in the report achieved a maximum waste package surface temperature at any time after emplacement of less than or equal to 85 degrees C.

The present repository development and operating concept utilized in the May 2001 TSLCC assumed that full scale surface and underground facilities at the repository and a rail spur connecting the repository to existing rail lines would be built as quickly as possible after a construction authorization from the U.S. Nuclear Regulatory Commission (NRC). Operations would start in 2010 at 400 metric tons of heavy metal (MTHM) per year and reach projected target waste acceptance and emplacement rates (3000 MTHM per year) within 5 years. This scenario requires large near-term appropriations that may be difficult to attain.

As an alternative, the program has begun to consider a modular repository development and operating strategy. A much more gradual (and lower initial cost) scenario for underground development and waste emplacement using modular surface storage will be possible if limited funding is available. This alternative would permit limited licensed disposal as quickly as possible, while deferring large-scale disposal. Acceptance objectives could be accommodated through surface storage. The *Preliminary System Design Alternatives Study for License Application* is in development.

The TSLCC will be updated at specific intervals consistent with the design effort. Key milestones in the design process will trigger major estimate updates (e.g., 30% design, 70% design, etc.). As we progress in the design process, more of the costs will be supported by bottoms-up estimates.

2. INDEPENDENT COST ESTIMATE (ICE) REVIEW

The ICE Review identified four major, twenty supporting, and twenty "Other" observations:

- Major Observation #1 - Schedule (3 supporting observations)
- Major Observation #2 - Cost (10 supporting observations)
- Major Observation #3 - Cost Drivers & Estimating Methodology (7 supporting observations)
- Major Observation #4 - Management Approach
- 20 "Other" Observations - Various Subjects.

BSC's assessment of the ICE Review concludes that the overall rate of contingency and the engineering and construction schedule were the most significant issues identified. It is important to note that the TSLCC estimate is defined as an **Order of Magnitude** estimate with an associated accuracy range of plus or minus 40%. This accuracy range is consistent with the industry standards and the DOE estimating guidelines. Excluding contingency, BSC believes the May 2001 TSLCC estimate is within this accuracy range. BSC concurs that contingency is understated. The contingency used in the TSLCC is slightly under 20% overall. Based on Bechtel's historical experience for projects in the planning phase, contingency should be in the 20% - 30% range, or higher.

At the time the May 2001 TSLCC estimate was prepared, a 2010 waste receipt and emplacement schedule was deemed achievable based on the associated program scope of work, execution approach, and schedule. However, it should be noted that the schedule was aggressive and had no schedule contingency. Opportunities to reduce the magnitude of construction effort and build contingency into the schedule exist through repository design optimization, modularization of facilities, and refinement of execution approach. Evaluation of these schedule improvement options was not included in the scope of the ICE Review.

Schedules for alternative scenarios have been and will continue to be evaluated, including modular construction scenarios with significant reductions in the required amount of construction prior to waste receipt and initial emplacement. It may be possible to optimize the first receipt schedule through early start of off-site construction of non-nuclear elements, reduced construction requirements for the first surface and subsurface modules.

Many of the other observations identified important issues that will be resolved without any cost impact as the project advances. Considerable ICE Review emphasis was placed on estimating methodology. These deficiencies were largely corrected during FY01.

The ICE Review indicated a need to improve the estimating methodology. In particular, the ICE team found a need for a formal update (to include a disciplined review and approval) of the time and motion study and for compilation of the cost estimate in a manner consistent with the DOE Cost Estimating Guide 430.1-1. BSC is planning to update the time and motion study in FY 2002. As for the estimating methodology, BSC has initiated corrective actions associated with cost estimating methodology. Two relational database systems have been acquired, estimating personnel have been trained, and May 2001 TSLCC data have been migrated into these systems. During the migration process, each estimate record was coded to the BSC Standard Code of Accounts structure. The classification of estimate data facilitates the sorting, grouping, summarization, and reporting of costs, man-hours, and quantities in a consistent manner. BSC will prepare all future TSLCC estimate updates and all other Yucca Mountain cost estimates in full compliance with the DOE Cost Estimating Guide and in accordance with standard BSC and industry practices.

For more specific details associated with each of the observations, see the Burns and Roe ICE Review Report (Burns and Roe 2001) and the responding BSC Report (BSC 2001b).

3. LOWER TEMPERATURE REPOSITORY

The *Life Cycle Cost Analysis for Repository Flexible Design Concepts* (BSC 2001a) provides life cycle cost analyses for repository lower temperature operating modes, supplements the May 2001 TSLCC estimate, and provides input to the Final Environmental Impact Statement.

The thermal goal for the repository design and operating modes analyzed was a maximum average waste package surface temperature at any time after emplacement of less than or equal to 85°C. The following design and operating parameters were varied to achieve the thermal goal:

- Waste package spacing
- Waste package size

- Ventilation (mode and duration)
- Staging (aging) of commercial spent nuclear fuel (CSNF) prior to emplacement
- Drift spacing.

In addition, the following cost-reducing measures were considered in the analysis:

- Variable waste package spacing
- Non-contiguous drip shields for scenarios involving increased waste package spacing
- Variable drift spacing
- Varying surface facility size and operating costs to reflect processing loads.

Seven low temperature scenarios were analyzed in this report:

- **Scenario 1** - extended ventilation (50 years forced, 250 years natural), no CSNF aging, increased waste package spacing.

- **Scenario 2 -** extended ventilation (50 years forced, 250 years natural), no CSNF aging, smaller waste packages (12 assembly Pressurized Water Reactor and 24 assembly Boiling Water Reactor), reference waste package spacing (0.1 meter).

- **Scenario 3 -** extended ventilation (300 years forced ventilation), no CSNF aging, reference waste package spacing, increased drift spacing (120 meters).

- **Scenario 4** - limited forced ventilation period (~100 years after last waste package is emplaced), no CSNF aging, increased waste package spacing.

- **Scenario 5 -** limited forced ventilation period (~75 years after last waste package is emplaced), aging of approximately 100 percent of the CSNF for 30 years after receipt, increased waste package spacing.

- **Scenario 6 –** limited ventilation period (~55 years after last waste package is emplaced), aging of approximately 50 percent of the CSNF for 30 years after receipt, increased waste package spacing.

- **Scenario 7** – extended ventilation (300 years forced ventilation), no CSNF aging, increased waste package spacing.

Each of the above scenarios was analyzed for a 97,800 MTHM waste stream consistent with the waste stream developed for the May 2001 TSLCC estimate in *Operational Waste Stream Assumptions for TSLCC Estimates* (CRWMS M&O 2000).

Only the results for the 97,800 MTHM scenarios (which can be directly compared to the TSLCC) are presented here.

Table 1 lists the key design parameters for the low temperature scenarios, along with those of the reference case May 2001 TSLCC.

Table 1. Low Temperature Scenario Key Design and Operational Parameters

Parameter	Reference Case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Linear Heat Generation Rate (kW/m)	1.33	1.00	1.00	1.33	0.70	0.50	0.60	1.13
Waste Package Spacing (m)	0.1	1.8	0.1	0.1	4.7	3.8	4.0	1.0
Emplacement Period (years)	31	31	31	31	31	71	61	31
Year of Last Emplacement	2040	2040	2040	2040	2040	2080	2070	2040
Closure Date	2119	2349	2349	2349	2149	2155	2134	2349
Surface Aging (years)	0	0	0	0	0	30	30	0
Approx. Percent of CSNF Aged	0	0	0	0	0	100	50	0
Waste Package Size	Reference[1]	Reference[1]	Small	Reference[1]	Reference[1]	Reference[1]	Reference[1]	Reference[1]
Drift-center to drift-center spacing (m)	81	81	81	120	81	81	81	81
Years of forced ventilation after emplacement period is complete	69	50	50	300	100	75	55	300
Years of natural ventilation after forced ventilation period is complete	0	250	250	0	0	0	0	0

[1] Reference = waste package sizes used in the May 2001 TSLCC (DOE 2001a)

Table 2 shows the results of the life cycle cost analysis. The costs are presented in terms of future costs (after 2000). In addition, the net present value of costs incurred after 2119 (the last year of operation for the reference case) is shown for three values of the real interest rate.

Table 2. Summary Cost Results for 97,800 MTHM Scenarios

Parameter	TSLCC	Scenario Number						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Total Future Cost (Billions of 2000 $)	49.3	56.3	62.0	61.1	56.8	64.9	60.6	63.4
Future Cost Through 2010 (Billions of 2000 $)	9.0	9.1	9.3	9.0	9.1	8.6	8.6	9.0
Future Cost Through 2020 (Billions of 2000 $)	19.2	19.6	21.1	19.2	20.1	18.4	18.7	19.4
Future Cost Through 2119 (Billions of 2000 $)	49.3	44.8	49.6	44.4	47.7	55.5	53.1	45.0
Future Cost 2120 to End (Billions of 2000 $)	0.0	11.4	12.4	16.7	9.1	9.5	7.5	18.4
Net Present Value, 2120 to End - 1% Real Interest Rate (Billions of 2000 $)	0.0	2.6	2.7	5.1	7.4	7.4	6.9	5.5
Net Present Value, 2120 to End - 2% Real Interest Rate (Billions of 2000 $)	0.0	1.1	1.1	2.6	6.1	5.8	6.4	2.8
Net Present Value, 2120 to End - 3% Real Interest Rate (Billions of 2000 $)	0.0	0.7	0.7	1.7	5.0	4.7	5.9	1.8

Fee adequacy was approximated for the various scenarios utilizing the same implementation of the Federal Register notice methodology as used in the May 2001 Fee Adequacy Report (DOE 2001b). Using a real interest rate based on projected 10-year Treasury Bond interest rates, it was concluded that the Nuclear Waste Fund balance in 2042 (after completion of waste receipt) was adequate to cover future costs for all scenarios. However, the Nuclear Waste Fund balance was reduced from the level in the reference case in some scenarios.

The approach to implementing the Federal Register notice methodology is sensitive to design considerations. The current implementation may require improvement to fairly allocate costs for low temperature design and operational features such as CSNF staging, extended ventilation, increased waste package spacing, and increased drift spacing. The adequacy of the current implementation of the methodology to properly account for the defense share costs is currently under review. Additional fee adequacy evaluations will be performed when an improved implementation of the methodology is adopted.

Based on the results of this analysis, several broad conclusions were drawn:

- For all of the scenarios, future costs through 2010 are not significantly different from the reference case (maximum $400 million difference). This reflects the result that the total cost necessary to begin operation of the repository is relatively independent of the subsurface operating mode chosen. In fact, for most of the scenarios, the total cost through the first 11 years of operation (2020) is not significantly different from the reference case.

- The cost increases in net present value dollars are, in general, significantly smaller than the cost increases in constant dollars. This is due to the timing of several of the principal cost increase contributors. For example, the scenarios involving extended ventilation increase costs several hundred years in the future, which has smaller impact on net present value than cost increases incurred prior to the end of emplacement. In addition, repository closure costs (e.g., drip shields), which are a significant contributor to total costs, are also pushed further out into the future by extending ventilation and/or emplacement times, which reduces their net present value impact.

- Staging commercial spent nuclear fuel to reduce heat output prior to emplacement provides flexibility to meet varying thermal design limits, but is one of the costlier options. Also, costs for this option are incurred during the construction and emplacement periods, and have a larger impact on net present value costs than options such as extended ventilation, whose costs are incurred during the monitoring period. In addition, the waste stream used for this analysis assumed that most of the CSNF received at the repository was aged at least 10 years. If the waste stream were "hotter" at receipt (e.g., more CSNF younger than 10 years old), more aging would be required to meet the same thermal goal. This would require more CSNF to be staged, further extending emplacement time and increasing costs. Any increase in the total waste quantity received (e.g., due to improved commercial reactor performance and operating license extensions) would also increase staging costs.

- Extended natural ventilation is the lowest cost method of lowering subsurface temperatures; however, it extends the pre-closure period by hundreds of years, which may have societal and/or licensing impacts. In addition, the annual monitoring cost (including maintaining drifts and ventilation shafts) is based on the 69 year post-emplacement monitoring period in the reference case. This assumption may not be valid for extended periods of monitoring, i.e., greater than 69 years. The maintenance cost for extended natural ventilation periods could be higher.

- The use of extended forced ventilation is one of the costliest methods of lowering subsurface temperatures. In addition, the annual costs of operating and maintaining repository mechanical equipment, drifts, and ventilation shafts are based on those estimated for 69 years of post-emplacement ventilation; the costs over a 300 year time period are more uncertain, and could be higher. There are also potential societal and/or licensing impacts from a long pre-closure period that have not been considered.

- The potential for lowering temperatures by increasing drift spacing, using smaller waste packages, or increasing waste package spacing is limited by the available repository emplacement area. In addition, using smaller waste packages not only requires more drift length, but also increases total waste package costs (since the cost of a waste package is not proportional to its capacity). Also, costs for these options are incurred during the construction and emplacement periods, and have a relatively larger impact on net present value costs than options such as extended ventilation, whose costs are incurred during the monitoring period.

It must be emphasized that the scenarios analyzed in this report were not all-encompassing. This analysis was a parametric study to demonstrate the relative cost impacts of varying certain combinations of design and operating parameters point-wise over a range of values. The actual design and operating mode chosen for the repository is likely to include some different combination of parameters than analyzed here, or possibly other features not analyzed in this report. The cost estimates themselves involved numerous assumptions and simplifications that render the absolute results uncertain (-30% to +50%). However, the cost differentials between scenarios are relatively accurate. A considerable amount of engineering design and analysis effort will be required to make a final decision as to the optimum design and operating modes to be chosen for the License Application design. Future TSLCC updates will incorporate the results of these final decisions.

4. FUTURE COST AND SCHEDULE IMPACTS

A few of the items that will directly impact future TSLCC schedules have already been identified, such as items from the ICE Review; the results of replanning of near-term work due to budget cuts; potential to move to a lower temperature repository; and/or utilizing a modular approach. Many other items will need to be considered as the project evolves over the next few years. Some examples are as follows:

- Site Recommendation and designation
- Consistency of budget appropriations with cost baseline
- Other schedule risk
- Trade studies / Value Engineering
- Revised reference design (to include security implications from September 11, 2001)
- Design optimization
- Flexible operating mode
- Markups / new contract impacts (BSC business model, e.g., overhead, General and Administrative)
- Potential options to recover some of the schedule.

It has become apparent that staged repository development that includes modular repository design and construction provides advantages in meeting Program schedules. A staged development approach using modular design provides a way to reduce construction costs through initial waste acceptance.

BSC has been directed to complete a design study and to recommend possible repository design solutions to support receipt and/or emplacement of waste as soon as practicable, beginning no later than 2010. Some of the items that will impact the cost and schedule are the following:

- Receipt date
- Receipt rate
- Emplacement date
- Emplacement rate
- Initial receipt waste types
- Funding profile and cost constraints
- Minimum and maximum closure times
- Maximum storage capacity and duration
- Drift orientation
- Emplacement drift backfill
- Available characterized area and horizon
- Post-closure thermal mode

- Waste quantity
- Early start of non-nuclear construction.

This study is a critical step on the path to the License Application design. As the design evolves, cost information will be "trended" into future TSLCC updates. The level of detail available will impact the level of accuracy and the amount of contingency applied. As the design matures, a more detailed "bottoms-up" approach to estimating will be applied.

5. FUTURE CHANGES TO THE TSLCC

Some of the elements that will affect the next TSLCC are as follows:

- New EIA Projections
  - Nuclear plant life extensions (more fuel)
  - Future nuclear plant capacity factors (affects amount of fuel)
- Possible changes to the number of DOE waste canisters
- Removal of immobilized Pu from the waste stream.

The TSLCC will be updated at specific intervals based on a schedule that is integrated with the design effort. This will allow the estimate to be updated in conjunction with key milestones in the design process and will maintain consistency between the estimate and the corresponding technical baseline.

The TSLCC planned to be performed in 2002 (calendar year) to support the Secretary's assessment of the adequacy of the nuclear waste fee will be based on trends and total project cost detail. The subsequent TSLCC will be developed in conjunction with the development of the preliminary design and will be based on trends and a partial bottoms-up estimate. A complete bottoms-up (30% engineering complete) based TSLCC will be completed in the following year.

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APPENDIX A

OCRWM TSLCC YEAR-BY-YEAR ESTIMATE

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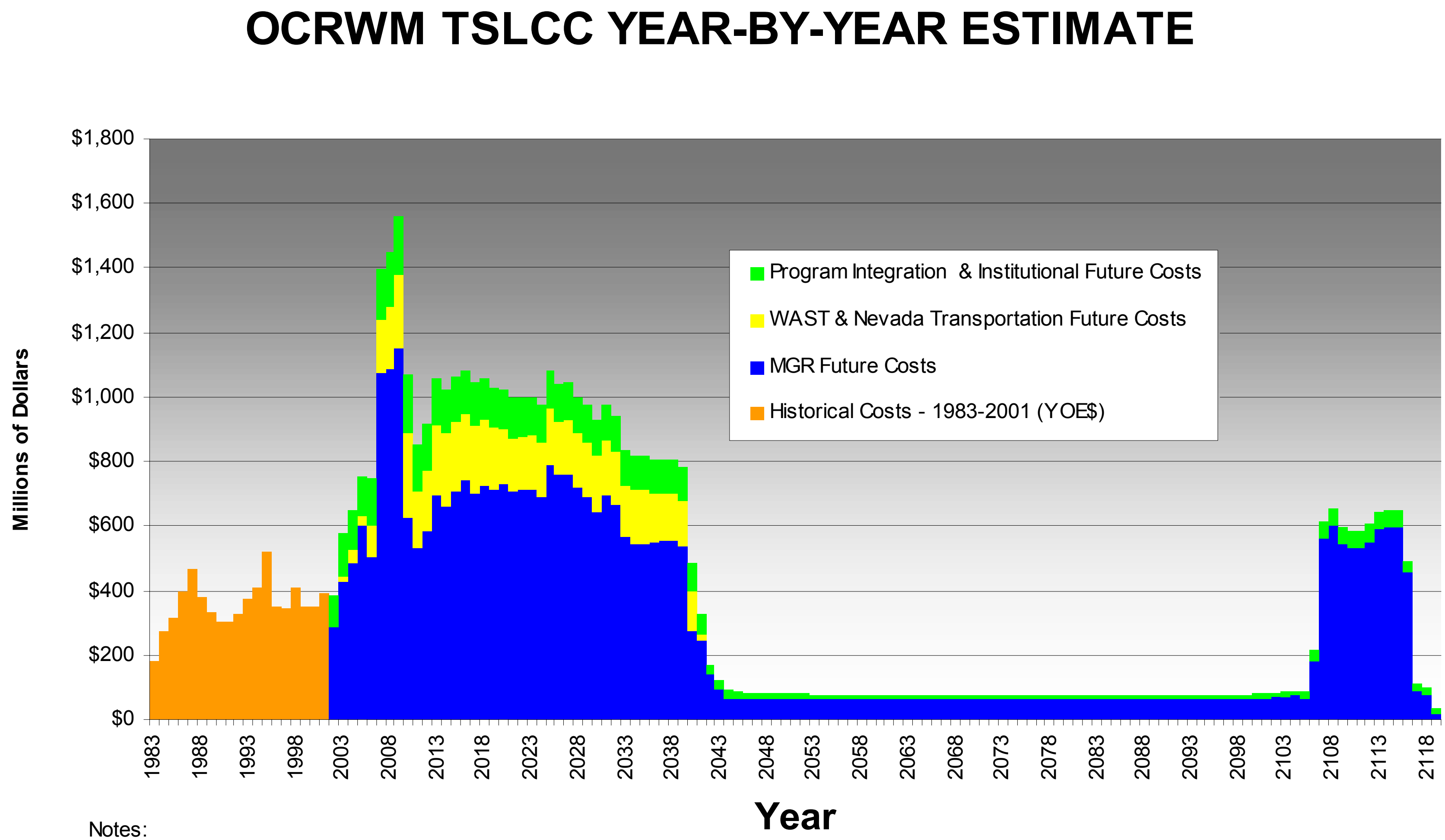

Notes:

* Historical Costs from 1983-2001 are shown as year-of-expenditure dollars (YOE$).

** Costs from 2002-2119 are constant 2000 dollars (2000$), i.e., not adjusted for inflation.

*** Graph reflects cost not budget requirements.

Figure A-1. OCRWM TSLCC Year-by-Year Estimate